The Architecture Decentralised Autonomous Organisation: a stigmergic exploration in architectural collaboration.

DOUNAS, T., VOELLER, E., PROKOP, S. and VELE, J.

2022

The Architecture Decentralised Autonomous Organisation

A stigmergic exploration in architectural collaboration

Theodoros Dounas[1], Elizabeth Voeller[2], Simon Prokop[3], Jiri Vele[4]
[1,] Robert Gordon University / archiDAO.io, [2,]archiDAO.io, [,3,4] Czech Technical university in Prague / archiDAO.io
[1]t.dounas@rgu.ac.uk [2]lizvoeller@gmail.com [3,4]{simon.prokop|jiri.vele}@fa.cvut.cz

We present "ArchiDAO", a decentralised Autonomous Organisation, i.e an architecture studio run on via smart contracts on the Ethereum blockchain. The objective of the paper is to offer a concise framework for the transformation of the way architectural work is conducted, via stigmergic principles, realised on smart contracts. The paper follows a systematic review of the Viable System Model, collective authorship in architectural design and previous DAO software stacks to extract a set of stigmergic principles. We conclude the paper with a discussion and a proposal for a basic set of smart contracts that can regulate the ArchiDAO operations.

Keywords: *Blockchain, Organisational Design, Viable System Model, Stigmergy.*

INTRODUCTION

We aim to implement a web3 approach into the Architecture, Engineering and Construction (AEC) industry to make it more productive, integrated and resilient. We will do this by building ArchiDAO, the first decentralised web3 design and educational studio for physical-digital product solutions and experiences.

The Architecture, Engineering and Construction (AEC) industry is fragmented, unproductive, and resistant to innovation. With a slow rate of return, the AEC industry rarely invests in digital innovation. Through earlier research, we developed prototypes for the AEC industry that integrated AEC's main platform today–Building Information Modelling (BIM)–with blockchain protocols [Dounas et al 2019,2020,2021]. This work also explored one model of how an architecture distributed autonomous organisation (DAO) could create design decisions [Lombardi et al 2019], while we extended additionally to discussing the way blockchain technologies can be the digital infrastructure for a circular economy in AEC. Our earlier research showed that many AEC processes are conducted ineffectively and would benefit from the automation that smart contracts introduce. Our vision is that blockchain-based tools and modes of operation will transcend the whole lifecycle of the AEC industry, from design to construction, operations, and decommissioning. We believe that our model of smart contracts will transform the industry into a more productive, integrated, and resilient industry.

Blockchain technologies and web3 will bring transformational change not just to the AEC industry, but all people who experience spatial structures– whether physical or virtual. For example, coupling blockchain primitives with architectural design could facilitate new models of collective

authorship for buildings. We can couple economic behaviours and incentives into spatial design to transform the use and maintenance of space. We could also incentivise improved environmental and carbon-equivalent performance in the industry: tokens could incentivise design strategies that reduce carbon emissions, or non-fungible tokens for building components can enable a new circular economy.

OBJECTIVES

The objective of the paper is to offer in concise format a conceptual and practical framework for the organisational transformation of the discipline of architecture, reinforcing collective authorship, non-extractive and regenerative processes, by harnessing the Decentralisation afforded by blockchain technologies. We thus describe the creation of a Decentralised Autonomous Organisation for Architecture based on stigmergic principles. Flanking this we also explore questions that discuss whether you really do need a blockchain in Architectural Design [Hunhenvicz 2020], which are the premises of collective authorship and collaboration in design, and what are the hierarchies that perform best for collective authorship?

Background

To describe the potential of Blockchain and DAO governance structure in the AEC industry, we provide the following concept and technology definitions. A Blockchain is a distributed ledger technology where information is stored on blocks of data in sequence, with nodes participating in the computer network storing a full copy of the ledger. The blocks contain an index number, a timestamp, data that we want to store in them, and a crypto-hash of the previous block. Each block contains information that is encrypted into a hash and contains the previous block's hash. This mechanism creates an immutable chain between blocks, hence the name blockchain.

Due to its distributed network nature, there is a goal of establishing a common, agreed upon version of consensus between all the nodes of the network. That by itself wouldn't pose a huge challenge if every network actor would be totally honest and truthful. Since that doesn't exist in the real world, the search for consensus might be targeted by malicious actors in order to write false transactions into the blockchain effectively stealing value from others. In order to prevent such behaviour cryptoeconomic incentives are introduced to persuade actors to adhere to true transactions. The nodes which validate consensual truth get rewarded for their effort.

Most common consensus approaches are Proof-of-Work and Proof-of-Stake mechanisms. Blockchains such as Bitcoin, or Ethereum are currently operating on PoW. Nodes on the network compete between each other in solving complex mathematical equations that prove the creation of a new block, thus validating an operation. This is called mining and a successful miner gets a reward for mining a new block. The complexity of the task and energy spent solving it prevents malicious actors from trying to compete with the entirety of the network. Such an attempt would require an impossible amount of energy and computation power.

In the case of Proof-of-Stake mechanism there is no solving of complex equations which can make running the whole blockchain 99.95% more energy effective. The consensus is reached by validator nodes. To become a validator node one has to deposit a substantial amount of cryptocurrency into a vault as a stake. Then one of the validator nodes is selected randomly to check all the transactions in the block. The probability of being selected is proportional to the size of the node's stake. If the transactions validated by the node prove to be fraudulent a portion of its stake is removed which disincentivises validators from getting involved in malicious action.

For our research we chose Ethereum blockchain and its second layers as it provides many benefits. It is essentially a Turing-complete state machine that allows the recording of a variety of information on

the Ethereum Blockchain. It is also programmable through code in a range of computer languages. Code stored and executed on Ethereum is called a smart contract and is immutable, verifiable and autonomous. Second layers are being built on top of Ethereum to increase processing speed and reduce gas price, which represents a fee for implementing and interacting with smart contracts. The most popular currently are Polygon, xDai, Optimism, Arbitrum, Parastate and Carthesi. One can create a token with various purposes and functionalities on a smart contract. Difference between cryptocurrency and tokens is that cryptocurrency has its own blockchain, which provides on-chain security. Tokens must rely on blockchain security on top of which exists. This makes token creation much easier. Ethereum provides several ERC standards, which are an open-source blueprint for launching a new token on top of ethereum. For fungible tokens ERC20 is recommended, for non-fungible (NFT) ERC 721 and ERC1155 can be used. This level of automation, transparency and ease of launching new tokens lead to emergence of whole decentralised ecosystems, called DAOs (Decentralised Autonomous Organisations). These organisations are using smart contracts for its governance and tokens for funding their operations.

An overview of Stigmergy

A core concept that we will use throughout this paper is the idea of stigmergy, or a universal, self-organising mechanism. The term originates from biology and the study of social insects and is used to describe the "decentralised informational infrastructure" employed by species like ants, termites, and honeybees. French entomologist Pierre-Paul Grassé was the first to use the term (a combination of the Greek words "stigma" and "ergo") to refer to signals embedded within previous work to motivate future work. Stigmergic mechanisms, therefore, refers to simple behavioural rules that lead to complex outcomes. For example, honeybee colonies utilise chemical pheromones to communicate information according to simple rules, which leads to overall coordination (such as role designation) for the collective organisation of the hive. These stigmergic principles allow individuals to collectively act as one, even if each individual has limited information about the whole. This ensures that ignorance at the agent level does not slow down coordination.

METHODOLOGY

This paper follows a systematic reviews approach, examining a triplet of themes: the viable system model of Stafford Beer, collective authorship in architectural design, and the governance approaches of existing DAOs. While most DAOs have focused on decentralised finance or similar endeavours, very few DAOs have emerged that seek to produce material artefacts such as buildings. From this systematic review we extract "Stigmergic Principles" which we develop into a set of guidelines for the smart contracts and operational procedures of ArchiDAO.

Viable System Model

The selection of the Viable System Model (VSM) for our review stems from the search for examples and implementations similar to the "CyberSyn" model that was developed in Aliente's Chile. According to Raul Espejo, the VSM is a "tool to steer interaction in directions that produce effective structural mechanisms." VSM develops along three guidelines: Policy, Cohesion, and Intelligence. Additionally, the VSM is built around three pillars, Cybernetics, the law of requisite variety and recursion. Within his introduction to the viable system model Espejo clearly describes how a collective of people is trying to find a common path forward, without previously having had a predetermined structure, or where a group of people come up with organic growth, by developing synergistic relationships within one another, a stigmergic approach. Ibrahim et al, describe how one can use the Viable System Model, to capture iterative features within architectural design processes. Within their description of the VSM, explicit mechanisms of decentralisation

emerge, in the same manner that emerge in Espejo's description, of autonomous units operating in a cohesive manner, where the organisation is decentralised, i.e there is no top-down structure to impose behaviour. Iteration in this manner is the "goal-oriented progression between steps of the design process that may contribute to a change in the design state". Within the VSM a recursive structure emerges, where units are recursive, i.e autonomous, and might contain other sub-systems that are also recursive and contain self-organised and self-regulated characteristics. To be able for the autonomous units though to provide services to the wider organisation, they need to communicate and effectively regulate themselves and in concert with the rest of the units. As such a decentralised model of governance is sketched.

Collective Authorship in Architectural Design

While the public narrative of architecture frequently discusses single authorship of architecture, where the sole architect is the single instigator of ideas, Architecture has become a truly transdisciplinary field where the act of design and construction is always an outcome of shared effort. Embedded within this is the manner in which work, and labour and expertise is organised, to produce a collective work. This drives new research in the ways of collaborating, communicating and collective authorship. With a focus on the architectural computational design, We have conducted a systematic review of peer reviewed papers from the CUMINCAD index searching for papers that discuss issues of collective authorship. We have found 37 papers, which we further filtered based on whether they discuss collective authorship in architectural design. We can derive that a significant portion of the papers we found covers the ways of collaborating remotely, using computer protocols to foster better communication, and sharing of data and knowledge.

For the goals of this paper, we further asked if there is also focus on selected stigmergic principles. We used a simple four-stage grading scale to indicate how much a certain principle is present and discussed in a paper.

- P1: Communication between members
- P2: Communication between members and object
- P3: Feedback loop?
- P4: Remote collaboration?
- P5: Computer protocol involved?
- P6: Are shared commons involved?
- P7: How decentralised a system is?
- P8: Is there the idea of a substrate?

Each of these principles was then scored indicating how frequent it is in the scope of the relevant papers. The highest scores were collected by principles of communication both between members and between the design object and members. Also, there is significant focus on remote collaborations and its influence on teaching or design quality. When we start to evaluate if the collaboration was enabled using a computer protocol, we can observe that the score gets lower, signifying the absence of a computer protocol for communication. Regarding the type of design project involved in the research paper, the principle of shared commons is present more in larger scale ones, which is understandable since public spaces are overall larger than private ones. However in the case of the principle of decentralisation or the influence of a central entity governing the collaboration, the score is the lowest which suggests that there might be a knowledge and practice gap, which might be an interesting opportunity for further research. The score of the idea of a substrate playing a significant role was the hardest to evaluate, since none of the papers mention it not even implicitly. We can however conceptualise it and then find traces in a couple of the papers. This establishes even further, in tandem with decentralisation, that there exists a similar knowledge gap where further research is needed in this area in order to be used as a governing and managing principle. [Table 1]

Table1
Classification of Papers on collective authorship in Architectural Design

No	Authors	Year	P1	P2	P3	P4	P5	P6	P7	P8
1	Merrick, Gu	2011	2	3	3	3	3	1	1	1
2	Fioravanti, Loffreda	2009	3	3	2	3	3	3	0	1
3	Dortheimer, Neuman, Milo	2020	3	3	3	3	2	3	1	1
4	Vallejo et Al.	2017	3	2	2	3	2	1	0	1
5	Eleutheriou et Al.	2015	3	2	1	0	0	2	1	2
6	Angulo, Fillwalk, Velasco,	2009	3	3	1	3	3	2	1	1
7	Yaniv Ophir	2009	3	3	3	0	0	1	0	1
8	Jose Sanchez	2015	1	3	3	1	3	3	2	2
9	Hsieh Chih-Wen	2005	3	3	1	3	2	0	2	1
10	Velasco	2007	3	2	1	3	2	3	1	1
11	Abdelmohsen, El-Khouly	2004	3	1	3	3	1	1	0	0
12	Dorta et Al.	2019	3	3	3	2	2	2	1	1
13	Schnabel, Ham	2013	3	3	3	1	2	2	1	2
14	Briscoe, Hadilou	2013	2	3	3	3	3	2	1	2
15	Adamantidis,Kidao, Tsiliakos	2013	2	3	2	0	3	1	0	2
16	Merrick et Al.	2011	3	3	2	3	2	2	0	1
17	Paulini, Maher, Murty	2011	3	3	2	1	2	1	1	2
	PX: Score		46	46	38	35	35	30	13	22

Governance in Existing DAOs

A key theme resonant in today's DAOs is distributed collaboration and the use of prescribed governance to protect and foster coordination. Two popular examples of projects that provide tools to facilitate DAO governance are DAOstack and Colony. In fact, the groups that create these tools for DAOs are DAOS themselves. DAOstack's mission is to "build collaborative networks," while Colony's goal is to "enable decentralised, self-organising companies." Both employ the concept of *reputation* to assign influence in organisational decision making.

According to DAOstack, successful DAOs have their own token to manage resources, their own reputation system to manage collaboration and decision making, and their own governance systems ("bylaws") to form the framework by which decision making can flow. Reputation is formalised as "reputation score units," which are non-transferable assets awarded to members based on predetermined merits and contributions to the organisation. This reputation score is representative of a member's influence in the organisation and can be used for internal decision making.

A defining element of DAOstack is their use of "holographic consensus" to scale governance. In creating this system, DAOstack first identified the resource most scarce to their governance: people's attention. Their process seeks to then elevate this scarce resource by monetizing it and utilising it within edge decision making. They therefore encourage the status of non-majority groups through the concept of boosting, in which people spend tokens to either promote or de-promote a proposal for the DAO to consider. This allows non-majority members to capture the attention of the collective entity. Tokens spent on boosting are different from the reputation scores used in internal decision making, and thus two feedback loops are created.

Colony adopts a similar approach to reputation, in which "members are compensated for the value they create for the colony." This value is non-transferable and decays over time, meaning the colony values recent behaviour and members are incentivized to contribute over the lifetime of the organisation.

To address scalability, reputation is awarded to members for the skills they use in domains. As Colony writes in their white paper, "By earning Reputation in a Skill (e.g. Javascript) and a Domain (e.g. BigCo Client Project), the recipient earns proportional influence in decisions pertaining to those skills and domains." Distributing the value of reputation into different skills and domains facilitates the creation of nearly decomposable sub-groups, which are "potentially independent, and can work without interactions among them in a stigmergic manner."

Another way that Colony addresses scalability is by minimising the importance of voting altogether. Decisions for the DAO are approved by default and voting only takes place when there is an objection. One benefit of this approach is reducing the costly complexity of computing and encoding every decision on the blockchain (i.e. "on-chain"). This is the same reason that Colony evaluates members' reputation off-chain, to avoid unnecessary cost. A simpler reputation mining protocol is used on-chain.

DISCUSSION: STIGMERGIC PRINCIPLES

In all three examples described, organisation is facilitated through predefined modes of communication that ultimately create feedback loops. This communication does not necessarily mean set meetings or written memos, but rather pre-defined modes of transmitting information and what that information means. Information transfer should not be one way and open ended, but rather feed on itself in either positive or negative feedback. For example, the intelligence function described in the VSM model refers to the groups' strategic knowledge of how to understand & respond to its environment, indicating a feedback loop. In the collective authorship process of architectural design, feedback loops are always involved in projects which aim to improve a design collectively. Within the DAOs examples, feedback loops use the decentralised medium, the tokens and smart contracts to operate. Additionally, behavioural rules (including value) are predetermined and utilise off-chain and on-chain modes to transmit that information in a continuous closed loop.

Stigmergic Principles

From this survey we can summarise six Stigmergic Principles that facilitate decentralised organisation.

- Feedback loops are established to achieve collective action
- Feedback loops can be encoded or non-encoded (or on- and off-chain in the blockchain context) as long as they are linked together for second order feedback
- There exist clear lines of communication
- There exist clear boundary conditions
- There exists clarity on where and how influence is generated and/or accrued
- There exists clarity on where influence can be used and for how long

We believe these Stigmergic Principles will aid the establishment of a new DAO for architecture.

Smart Contracts and Token Mechanisms in ArchiDAO

The gaps identified from our systematic review are those of decentralisation and the absence of a substrate medium. Decentralisation within the VSM exists with work units having autonomy and recursion, but also the potential for iterative work. A substrate medium is used in stigmergy to guide work, almost in the manner that a state machine works in computation. In parallel with exploring these in a theoretical manner, we seek to build them and the organisation around them to test the premise of decentralisation and stigmergy at scale. We propose thus three key smart contracts that regulate the mechanisms of the DAO on-chain: The ArchiDAO Non-Fungible-Token, is used to participate in the organisation for governance purposes, but also as a track record of the skills and experience of the member that holds the token, a series of project and staking contracts, through which ArchiDAO members engage with a project to produce work, and a Fungible Token that is used within the ArchiDAO treasury to reward members, and for expenses. (figure 1)

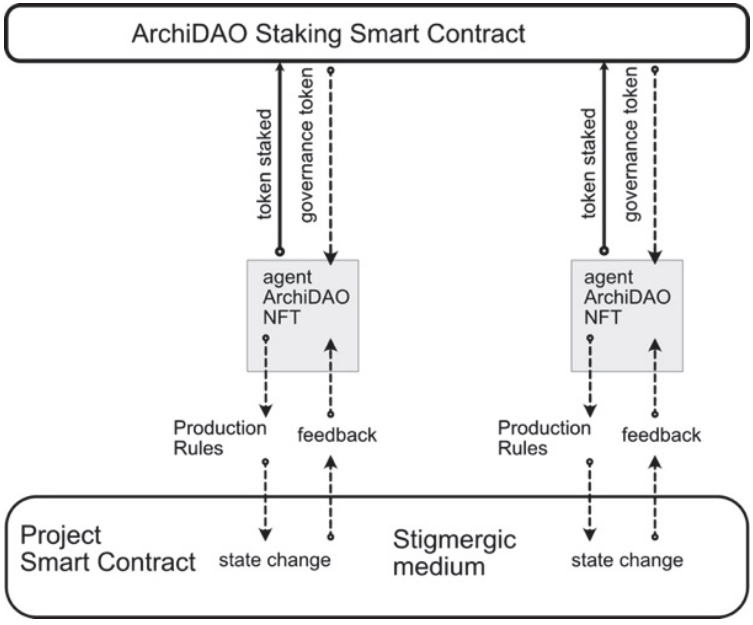

Figure 1
Smart Contracts as stigmergic principles for ArchiDAO

On a stigmergic level, The principle of pheromones can be observed in ArchiDAO internal project called ArchiDAO NFT. Each DAO member is given (mints) an NFT which records her skills in various fields. This effectively gives the member an identification which is rich in information - other members can observe what skills she or he has. Ownership of a ArchiDAO also serves the purpose of a clear boundary for DAO inclusion. By stating one's own skills to the community one already takes on an implicit role like

ant warriors, gatherers, builders or caregivers do. This broadcasting ability is comparable directly to pheromone trail.

An owner of an ArchiDAO NFT is then entitled to participate in a Project.NFT. Projects.NFT is minted by an ArchiDAO project leader as an NFT which contains the ArchiDAO project design brief and a collection of skill slots which describe the project's demands and needs. Owners of ArchiDAO NFT can then propose to fill a skill slot with their own skills up to a desired level by staking an amount of their dedication tokens to it. This helps the community to track and manage dedication of time. Pheromones are deposited with a gradient of strength which signifies the urgency or magnitude of the information shared.

Another part of the pheromone principle (the substrate) can be observed in Dashboard.NFT which tracks all the ArchiDAO.NFT and Project.NFT to know the state of the whole organisation. Active members are rewarded by tokens and NFT drops. This is a common approach in most of the DAOs. Value of these rewards is partially defined by the strength of its own community. If DAO is successful and manages to attract an active community, then the value of rewards increases in time. This is the driver for community members to help each other even without any direct gain, because by helping others they create a better community, which then increases the value of members tokens and NFTs.

REFERENCES

Abdelmohsen, S.E.-K. (2009) 'Representing Reflective Practice in a Remote Design Collaboration Process', in *Digital proceedings of the 3rd Conference of International Association of Societies of Design Research (IASDR 2009), COEX, Seoul, Korea, pp. 1317 – 1326*.

Adamantidis, E.M.K. and M.T. (2013) 'Siphonophore – A Physical Computing Simulation of Colonial Intelligence Organisms', in *Open Systems: Proceedings of the 18th International Conference on Computer-Aided Architectural Design Research in Asia (CAADRIA 2013) / Singapore 15-18 May 2013, pp. 355-364*. CUMINCAD. Available at: http://papers.cumincad.org/cgi-bin/works/paper/caadria2013_030 (Accessed: 25 March 2022).

Angulo, A.J.F.G.V. de V. (2009) 'Collaborating in a Virtual Architectural Environment: The Las Americas Virtual Design Studio (LAVDS) populates Second Life', in *SIGraDi 2009 - Proceedings of the 13th Congress of the Iberoamerican Society of Digital Graphics, Sao Paulo, Brazil, November 16-18, 2009*.

Briscoe, D. and A.H. (2013) 'Collective Intelligence: An Analytical Simulation of Social Interaction with Architectural System', in *Open Systems: Proceedings of the 18th International Conference on Computer-Aided Architectural Design Research in Asia (CAADRIA 2013) / Singapore 15-18 May 2013, pp. 375-384*.

Bonilla Vallejo, M.A.D.M. dos S. (2017) 'La práctica de la colaboración en los procesos digitales de diseño: Investigación - Acción [The practice of collaboration in digital processes design: Investigation action]', in *SIGraDi 2017 [Proceedings of the 21th Conference of the Iberoamerican Society of Digital Graphics - ISBN: 978-956-227-439-5] Chile, Concepción 22 - 24 November 2017, pp.106-113*.

Colony (2020) 'Colony' Technical White Paper commit 4915991. Available at: https://colony.io/whitepaper.pdf

DAOstack (2018) 'DAOstack' White Paper v1.1. Available at: https://daostack.io/wp/DAOstack-White-Paper-en.pdf

Dorta, T. (2019) 'Co-Designing in Social VR - Process awareness and suitable representations to empower user participation', in *M. Haeusler, M. A. Schnabel, T. Fukuda (eds.), Intelligent & Informed - Proceedings of the 24th CAADRIA Conference - Volume 2, Victoria University of Wellington, Wellington, New Zealand, 15-18 April 2019, pp. 141-150*.

Dortheimer, J. (2020) 'A Novel Crowdsourcing-based Approach for Collaborative Architectural Design', in *Werner, L and Koering, D (eds.),*

Anthropologic: Architecture and Fabrication in the cognitive age - Proceedings of the 38th eCAADe Conference - Volume 2, TU Berlin, Berlin, Germany, 16-18 September 2020, pp. 155-164.

Dounas, T. Lombardi, D. Jabi, W (2019) 'Towards Blockchains for architectural design - Consensus mechanisms for collaboration in BIM', eCAADe-SiGradi 2019, Porto Portugal

Dounas, T. Lombardi, D. and Jabi, W.: 2020, Framework for decentralised architectural design BIM and Blockchain integration, *Journal of Architectural Computing*, https://doi.org/10.1177%2F1478077120963376.

Dounas, T. Jabi, W. Lombardi, D. (2021) 'Non-fungible building components - using smart contracts for a circular economy in the built environment' 'Designing Possibilities' Sigradi 2021, ubiquitous conference, XXV International conference of the Ibero-american society of digital Graphics.

Eleutheriou, V.S. (2015) 'Design Thinking as collaborative tool for the development of human and intelligent cities towards the common good', in *SIGRADI 2015 [Proceedings of the 19th Conference of the Iberoamerican Society of Digital Graphics - vol. 1 - ISBN: 978-85-8039-135-0] Florianópolis, SC, Brasil 23-27 November 2015, pp. 51-56*.

Hsieh, C.-W. (2005) 'A Networked Sketching Environment for Supporting Collective Creativity', in *Digital Design: The Quest for New Paradigms [23nd eCAADe Conference Proceedings / ISBN 0-9541183-3-2] Lisbon (Portugal) 21-24 September 2005, pp. 197-204*.

Hunhevicz JJ, Hall DM (2020) Do you need a blockchain in construction? Use case categories and decision framework for DLT design options. Adv Eng Informatics 45:101094. https://doi.org/10.1016/j.aei.2020.101094

Ibrahim, R. Khaidizir, K.A.M. Zaeri, F. (2013) Viable System Model in Capturing Iterative Features within Architectural Design Processes, ACIIDS 2013, Asian conference on Intelligent Information and Database Systems, Kuala-Lumpur, Malaisia

Fioravanti, A.L. (2009) 'Formalizing and Computing Ontologies to Speed Up the Construction of Knowledge-based Collaborative Systems: Three Different Approaches', in *Computation: The New Realm of Architectural Design [27th eCAADe Conference Proceedings / ISBN 978-0-9541183-8-9] Istanbul (Turkey) 16-19 September 2009, pp. 341-348*.

Lombardi, D. Dounas, T. Cheung, L. H. Jabi, W. (2020). Blockchain for Validating the Design Process. In SIGraDI 2020. Medellin.

Merrick, K.N.G. (2011) 'Motivation, cyberworlds and collective design', in Proceedings of the 16th International Conference on Computer Aided Architectural Design Research in Asia / The University of Newcastle, Australia 27-29 April 2011, pp. 697-706.

Merrick, K.G.N. (2011) 'Supporting Collective Intelligence for Design in Virtual Worlds: A Case Study of the Lego Universe', in *Computer Aided Architectural Design Futures 2011 [Proceedings of the 14th International Conference on Computer Aided Architectural Design Futures / ISBN 9782874561429] Liege (Belgium) 4-8 July 2011, pp. 637-652.* CUMINCAD. Available at: http://papers.cumincad.org/cgi-bin/works/paper/cf2011_p016 (Accessed: 25 March 2022).

Sanchez, J. (2015) 'Block'hood - Developing an Architectural Simulation Video Game', in *Martens, B, Wurzer, G, Grasl T, Lorenz, WE and Schaffranek, R (eds.), Real Time - Proceedings of the 33rd eCAADe Conference - Volume 1, Vienna University of Technology, Vienna, Austria, 16-18 September 2015, pp. 89-97*.

Sanchez, J. (2018) 'Platforms for Architecture: Imperatives and Opportunities of Designing Online Networks for Design', in *ACADIA // 2018: Recalibration. On imprecisionand infidelity. [Proceedings of the 38th Annual Conference of the Association for Computer Aided Design in Architecture (ACADIA) ISBN 978-0-692-17729-7]*

Mexico City, Mexico 18-20 October, 2018, pp. 108-117.

Schnabel, M.A. and J.J.H. (2013) 'A Framework for Social Networked Architectural Education', in *Open Systems: Proceedings of the 18th International Conference on Computer-Aided Architectural Design Research in Asia (CAADRIA 2013) / Singapore 15-18 May 2013, pp. 313-322*.

de Velasco, G.V. (2007) 'A Group of Friends: The Las Americas Network, Virtual Studios, and Distance Education in Architecture', in *International Journal of Architectural Computing vol. 5 - no. 3, pp. 455-468*.